



# MARINE PHYSICAL LABORATORY

SCRIPPS INSTITUTION OF OCEANOGRAPHY

San Diego, California 92152

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## Nonlinear Dynamics and Internal Waves

### FINAL REPORT

Principal Investigator: H. D. I. Abarbanel

Final Report for Contract

N00014-83-K-0109

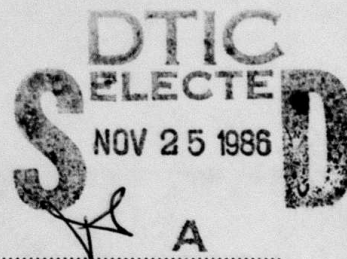
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For the Period: 1 January 1983 through 31 March 1985

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) During period of this contract research concentrated on two foci: (1) the evaluation of transport equations and transport coefficients relating to systems with widely differing spatial and temporal scales. This was motivated by the desire to understand the transfer of momentum, energy, etc., from the mesoscale to the smaller oceanic scales especially internal waves. (2) Nonlinear stability of fluid and plasma flows using this method developed by Arnol'd.		





## NONLINEAR DYNAMICS AND INTERNAL WAVES

Final Report  
Advanced Research Projects Agency  
Contract: N00014-83-K-0109  
Period: 1 January 1983 through 31 March 1985  
Principal Investigator: H.D.I. Abarbanel  
Total Award: \$120,000

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During the period of this contract -- 1/5/83 to 3/31/85 my research took on two foci: (1) the evaluation of transport equations and transport coefficients relating to systems with widely differing spatial and temporal scales. This was motivated by the desire to understand the transfer of momentum, energy, etc from the mesoscale to the smaller oceanic scales especially internal waves. (2) Nonlinear stability of fluid and plasma flows using this method developed by Arnol'd.

In the first focus I studied with my students Keeler and Buchsbaum model systems where one is high frequency and the other is "slow" relative to it. Taken together the total system is Hamiltonian -- energy conserving and phase space volume preserving. The slow part (representing the mesoscale oceanic phenomenon) will transfer energy and other physical properties to the more rapid system and thus "look" as if it is dissipative on time scales dictated by the phase space correlation functions of the fast system. That time scale measures the rate at which information which enters the fast

system gets lost in the sense of forgetting its initial conditions or origin. This work is still in progress but has led to the formulation of the mesoscale problem in Hamiltonian terms and to the understanding of several model systems created to imitate the setup just described. The most interesting of these model systems has the intriguing property of possessing an apparently infinite number of attractors with basins of attraction which are of zero volume (i.e. have dimension less than the ambient phase space). This has major implications (not yet fully explored) for the predictability of dynamical systems including those of central relevance for fluid flow.

In the second year, I began the study of nonlinear stability of certain fluid and plasma flows. The major application of this has been a paper published in Physical Review Letters in June, 1984 followed by a longer paper to appear in the Philosophical Transactions of the Royal Society. The main result there is that the classical stratified, shear flow configuration which is linearly unstable when the Richardson number is less than  $1/4$  is nonlinearly stable when that dimensionless number exceeds unity. This is a result more or less conjectured since the 1920's and complements the linear Miles-Howard result from 1961.

Publications emerging from the contract period:

(1) Bifurcation Phenomena in Collisional Plasmas: Symposium on Nonlinear

Problems in Engineering, Argonne National Laboratory, April 1983.

(2) Richardson Number Criterion for the Nonlinear Stability of Stratified Flow, with D. Holm, J. Marsden, and T. Ratiu; Phys. Rev. Letters, June 1984.

(3) Hamiltonian Formulation of Nearly Geostrophic Flow, to be published in Geophysical and Astrophysical Fluid Dynamics, Fall 1985.

(4) Nonlinear Stability of Stratified Fluids with D. Holm, J. Marsden, and T. Ratiu to appear in Phil. Trans. Roy. Soc., Fall 1985.

(5) Symmetries and the Interpretation of Nonlinear Stability in Three Dimensional Fluid Flow with D. Holm to be published in J. Fluid Mech.

(6) An Iterated Map with an Infinite Number of Attractors with S. Buchsbaum and J. Keeler, to be published in Physica D.

During and just after the contract period I delivered talks at the following places on work done under the auspices of the contract: UCLA, University of Hawaii, UCSD, UC Davis, Los Alamos National Laboratory, ONR-NSWC Conference on Nonlinear Dynamics in May, 1985, Woods Hole Oceanographic Institution, and UC Santa Barbara. No written reports other than proceedings of the conference and the publications indicated above were issued.

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